A e o l u s

Distributed Control of Large-Scale Offshore Wind Farms

The project aims to provide new knowledge on how to dynamically model flows based on distributed sensor measurements and use this information as the basis for control of the flow resource.

At A Glance: Aeolus

Distributed Control of Large-Scale Offshore Wind Farms

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Partners:

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Industrial Systems and Control Ltd., UK

Lund University, Sweden

University of Zagreb, Croatia

Energy Research Centre of the Netherlands, The Netherlands

Vestas Wind Systems A/S, Denmark

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EC Contribution: *€2.5 Million*

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KEYWORDS: distributed control, model predictive control, reconfigurable control, estimation

Main Objectives

A key socio-economic challenge for Europe is: how to deal with a climate change, while meeting rapidly increasing demand for energy and ensuring security of supply? Wind energy can be a significant part of the answer. The new frontier of the wind industry is large-scale offshore wind farms.

Closed loop control of wind power installations has historically been decentralized and a collection of wind turbines in farms is a highly complex system with interdependencies through the shared resource, the wind. Wind turbines are affected by the wind but they also changes the wind field within the farm through the control.

Aeolus will focus on generating new knowledge on how to dynamically model flows based on distributed sensors and use this information as the basis for control of the flow resource.

To address objectives related to cost, quality of power and mechanical loads, models and control paradigms must be developed that allow wind resource allocation to individual turbines.

Inspired by the industrial case of complex large-scale distributed offshore wind farms, the project will provide coherent and scalable models and control principles that bridge the gaps between fluid dynamics, wind field modelling, computer and control engineering. The synergy between these different areas of research and development will support dynamic wind farm level control that exploits the interdependencies between wind turbines in order to increase energy performance and reduce the fatigue loads.

The research will facilitate a paradigm shift from wind turbine control to dynamic wind power system control using the geographically distributed turbines to measure and change the wind flow.

Technical Approach

The objective of Aeolus is to research and develop: 1) models that allow real-time predictions of flows and incorporate data from a network of sensors, and 2) control paradigms that acknowledges the uncertainty in the modelling and dynamically manages the flow resource in order to optimise specific control objectives.

The basis for increased energy performance of large-scale wind farms is knowledge of the wind field within and around the farm. To this end we intend to investigate time averaged quasi-static flow models that describe the flow of wind within the farm and the associated expected electrical power output and the expected mechanical loads.

To bridge the gap between a quasi-static flow model and individual wind turbine control, we investigate online dynamic modelling of deviations from the quasi-static model by online estimation.

Two alternative approaches are taken to control of the distributed system.

Model predictive and reconfigurable paradigms are developed that combine local controllers at each turbine with centralized supervision on a slower time scale. As a potentially more flexible approach, decentralized strategies are developed aiming for similar performance, but at the same time exploit potential advantages in terms of flexibility and robustness of a distributed solution.

To support development, validation and dissemination of the proposed research a simulated benchmark is created and the results are also physically validated on a scaled wind farm available at a partner site (ECN).

Key Issues

The technical approach described above, involves a number of key issues to be addressed:

1) Generic quasi-static flow models relating single turbine production and fatigue load to the map of wind speeds.

A time averaged quasi-static flow model derived from fluid dynamics and based on meteorological and wind turbine related measures.

2) Dynamic flow models describing deviation from a static model due to rapidly changing flow effects.

Dynamic flow models that allow predictions of the flow at all measurement locations. A modelling framework that supports online flow measurements and bridges the gap between a quasi-static flow model and individual wind turbine control.

3) Principles for supervisory farm power/load optimisation. Centralized control principles for farm level optimisation of flow resource allocation in order to meet farm level control objectives.

The control principles incorporate knowledge of the wind flow variations, provide robustness by addressing reconfiguration and at the same time minimize the (extreme and fatigue) loads experienced by turbines.

4) Principles for decentralized control of the wind power and fatigue load relations.

The basic approach for decentralization is to split the global design objective for the wind farm into separate utility functions for each turbine, then let the turbines cooperate by buying and selling support from each other in an on-line virtual market system.

5) Case study.

Models and simulation software to support coherence between the activities in Aeolus (both at the methodological and at the validation level), their combined application on a case study, their realization as components for farm level and turbine level control.

Expected Impact

Complexity. Aeolus will support a paradigm shift from single turbine control to farm level control, by investigating a centralized and a decentralized control principle.

New markets. Aeolus help develop the European leadership in the new market for large scale wind farms.

Efficiency and flexibility. Aeolus provides optimal solutions to maximize power production while minimizing structural loads. Flexibility is achieved by a distributed control paradigm.

Low-cost monitoring. Aeolus will provide new knowledge on how to generally predict dynamic flows based on monitoring of the speed and direction of the flow through a network of spatially distributed sensors.